

AD 681346

MULTIWAVELENGTH LASER PROPAGATION STUDY

Quarterly Progress Report No. 2

J. Richard Kerr

Oregon Graduate Center
for Study and Research
Portland, Oregon

December, 1968

Sponsored by

Advanced Research Project Agency
ARPA Order No. 306

Reproduction in whole or in part is permitted for any purpose
of the United States Government.

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va. 22151

This document has been approved
for public release and sale; its
distribution is unlimited.

DDC
RECEIVED
JAN 30 1969
C

**BEST
AVAILABLE COPY**

ACKNOWLEDGMENT

This research was supported by the Advanced Research Projects Agency of the Department of Defense, and was monitored by the Office of Naval Research under Contract N00014-68-A-0461-0001.

SUMMARY

The major objective of this program is to experimentally investigate the wavelength-dependence of turbulence effects on optical propagation through the atmosphere, and to relate the results to certain meteorological parameters, theoretical models, and model-independent dimensional analyses. The experiments are conducted with the use of simultaneous, spatially-coincident laser beams at three wavelengths in the visible and infrared spectrum, with real-time processing for the various statistical results.

A particular motivation is to establish the validity of wavelength-scaling laws as applied to a growing body of experimental data at visible wavelengths, in order to predict and optimize the performance of systems operating at certain infrared wavelengths. Techniques are emerging which will place great practical value on reliable predictions of turbulence effects for a given site and conditions.

During the second period, the low noise, stable lasers were acquired, the three-wavelength transmitter and receiver optical systems were constructed, and the computer electronics were completed. A newly acquired, flat site was established with necessary power, cooling, communications, and protective arrangements. The above systems are currently being installed at the site. The resultant facility will be uniquely suited to atmospheric propagation work, in terms of multiwavelength capability, data processing versatility, meteorological instrumentation, and attention to experimental detail necessary to achieve reliable results in this difficult field of investigation.

CONTENTS

Page

1	I. Introduction
1	II. Experimental Progress
5	III. Plans for the Next Period
7	References

Figures

8	1,2. Three-Wavelength Optical Transmitter
9	3. 9 kHz Chopping Wheel
9	4. Spatial-Correlation Receiver Structure
10	5. Three-Wavelength Detector System
10	6. Computer Electronics - Typical Modules
11	7. Transmitter Shack
11	8. Receiver Shack

Tables

2	I. Transmitter Parameters
4	II. Receiver Parameters

I. INTRODUCTION

The motivation and approach for this multiwavelength laser propagation study was described in Quarterly Progress Report No. 1. During the second period, the transmitter optics, receiver optics and mechanical system, computer electronics, and general meteorological electronics were constructed. A new, flat, one-mile site was established, and the above systems are currently under installation. The resultant facility will permit simultaneous, congruent-path measurements at three widely-separated wavelengths, with versatile data-processing capabilities and considerable attention to experimental detail.

The resultant measurements should aid significantly in the evaluation of current theoretical models and model-independent dimensional reasonings. In particular, although the analytical understanding of propagation through a random medium is improving, especially for conditions of strong turbulence or "saturation,"^{1,2,3} the fundamental assumption of local isotropy and an inertial subrange⁴ is highly questionable under many conditions.^{5,6,7} That is, the degree of theoretical understanding may be more limited by considerations of atmospheric physics than by perturbation mathematics. These points will be discussed in later reports.

II. EXPERIMENTAL PROGRESS

During the second period, the systems described in Quarterly Progress Report No. 1 were constructed, evaluated, and calibrated. This work will be briefly described here.

A. TRANSMITTER SYSTEM

The three-wavelength, combined-beam transmitting system has been completed and is shown in Figures 1 and 2. The three lasers were chosen for their stability and noise characteristics. Beams from the lasers are separately formed into f-32 cones and combined using dichroic optics. The focal planes of each beam coincide at the focus of a 6-inch Newtonian telescope, which is partially illuminated (off-axis) to avoid aperturing. The resultant beams leaving the transmitter are 1.5 inches in diameter, and are diffracted and/or defocused to result in a 1 meter spot at the receiver. Pointing is achieved by means of a gimballed mirror and fine steering of the entire telescope. The telescope mirrors are hard-aluminum-coated, with no overcoating which would interfere with performance at 10 microns. The entire system is mounted on a massive steel table.

The pertinent transmitter parameters are summarized in Table I.

Table I - - Transmitter Parameters

<u>Wavelength</u>	<u>Laser Type</u>	<u>Laser Power (TEM₀₀)</u>	<u>Laser Noise (rms)</u>	<u>Optical Transmission (includes barium flouride window)</u>
4880 A	Argon	0.9 Watts	0.96%	22%
1.15 μ	He-Ne	10 mW	0.53%	17%
10.6 μ	CO ₂ (sealed)	8 Watts	0.1%	68%

The transmitted beams are chopped at 9 kHz using a precision chopping wheel which was developed for the purpose (Figure 3). The wheel is located at the focal plane of the telescopes and mechanical imperfections (such as wobble) are negligible.

B. RECEIVER SYSTEM

As described in Quarterly Progress Report No. 1, the primary receiver consists of a variable-separation mirror drive for spatial correlation measurements, followed by a dichroic mirror and spike filter system to separate each wavelength into its appropriate detector. The system is shown in Figure 4. The rate of separation is variable down to a fraction of one cm/sec, and angular steering is negligible.

The detectors and associated electronics have been chosen and developed for maximum dynamic range, which is essential in log-amplitude data processing. At the visible and near-infrared wavelengths, appropriate photodiodes are mounted in modules with FET front-end and buffer amplifiers. At 10 microns, Ge:Hg dewars are connected directly to front-end modules. One set of detectors is shown in Figure 5.

The receiver characteristics, taking into account the use of 3 mm apertures with a 1 meter diameter beam, are summarized in Table II. The resulting SNR is based on quiet (non-scintillating) conditions. It is evident that sufficient signal will be present at 2 wavelengths to fully utilize the 80 dB dynamic range of the logarithmic electronics in the computer. At 1.15 microns, under conditions of strong scintillation, variances should be computed from the probability curves.

A special detector with a larger collecting aperture is utilized at 4880 Å to provide a reference of the chopping signal, for purposes of synchronous demodulation.

Table II -- Receiver Parameters

<u>Wavelength</u>	<u>Detector Type</u>	<u>Receiver Optical Transmission</u>	<u>Received Optical Power at Detector</u>	<u>SNR (1 kHz bandwidth)</u>
4880 A	Silicon photodiode, ultra-low leakage	32%	8×10^{-7} W	> 80 dB
1.15 μ	Infrared silicon photodiode	13%	10^{-8} W*	35 dB
10.6 μ	Ge:Hg	76%	5×10^{-5} W	> 80 dB

*The radiation at 1.15 microns is defocused in one plane only, to decrease geometrical loss and conserve signal.

C. COMPUTER ELECTRONICS

The special-purpose analog computer described in Quarterly Progress Report No. 1 has been completed. The basic elements are shown in Figure 6. There are six buffer - synchronous demodulator stages, one of which is shown on the left. These are followed by three log-correlation and probability-curve units, one of which is shown on the right. The rack-mounting control panel is shown in the center of Figure 6. The dynamic range is 80 dB, and averaging times of up to 100 seconds are provided.

The resultant data will be recorded on a four-track FM instrumentation tape recorder, Sony Type PFM-15. One track will be used for each wavelength, while the fourth track provides identification and a reference

such as mirror separation (cross correlations) or reference amplitude (probability density). These results will then be plotted on a chart or XY recorder and/or used for further (digital) processing.

It is worth noting that the small laser noise levels (less than 1% each) will not affect the dynamic range performance discussed above. The only effect of this noise will be to contribute to errors in very small variances or cross-correlations; these are not of particular practical importance.

D. METEOROLOGICAL INSTRUMENTATION

The system for the determination of the refractive index structure constant, C_N^8 , is under construction as described in the previous report. Equipment has been assembled for the continuous recording of pressure, humidity, temperature, wind velocity, and wind direction.

E. SITES

Buildings have been installed on a new, flat propagation path of approximately one mile in length, at a field 14 miles from the Center. The shacks are insulated and heated, and provided with double locks and remote alarms against vandalism. The transmitter shack (Figure 7) has been provided with three-phase power for the argon laser, as well as an external heat exchanger and pump for recirculating laser cooling water. The receiver shack (Figure 8) is provided with a slit opening for spatial correlations and a large opening for aperture-averaging measurements. The two shacks and the Center are linked by radio.

III. PLANS FOR THE NEXT PERIOD

The systems described above are now being installed at the new site. The logistics of establishing a new site, with zoning, power, and communications problems, combined with the late delivery of a number of major and

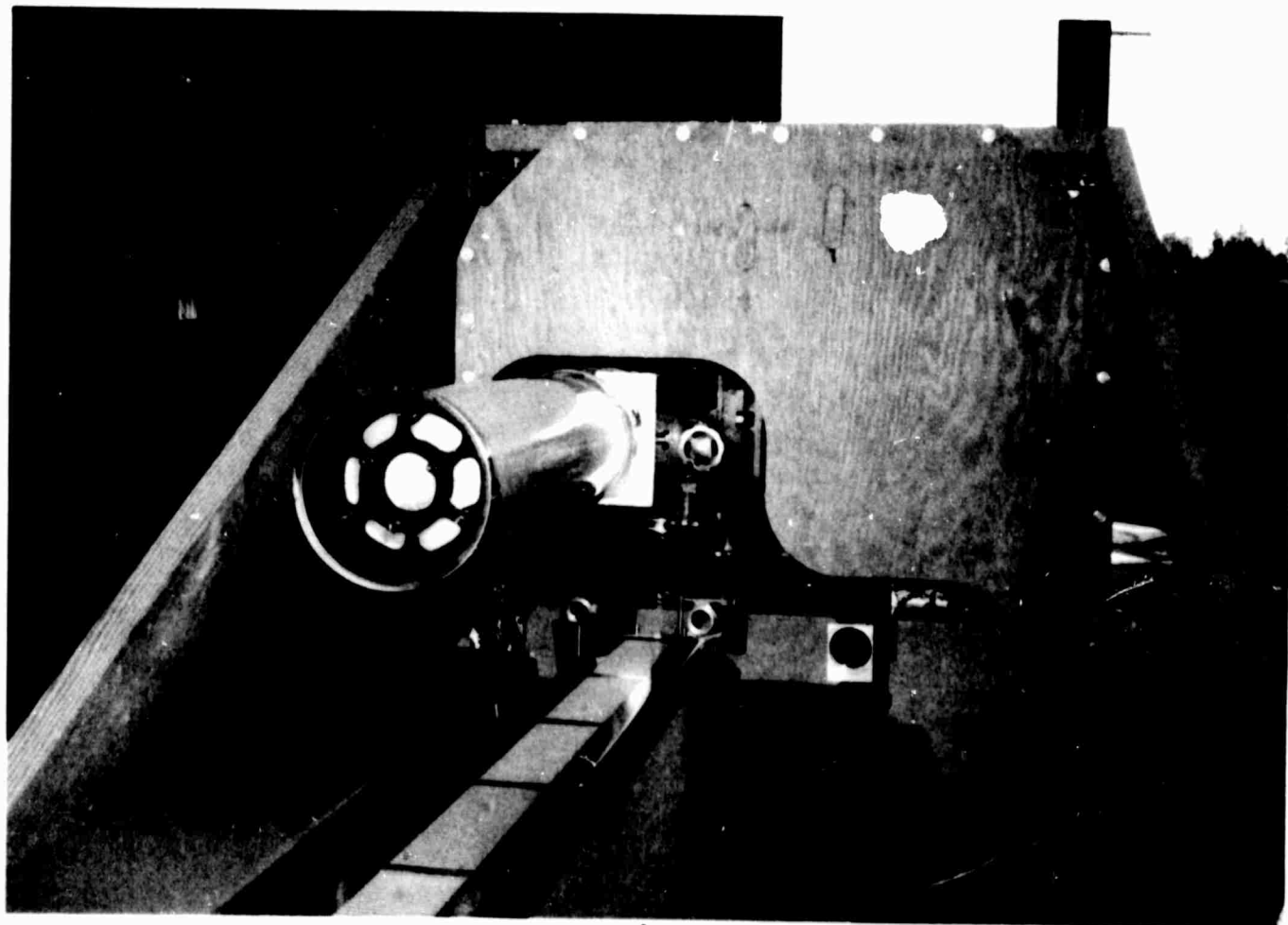
minor optical and electronic components, have resulted in our being delayed from our original schedule by several weeks. However, the versatile capability of the facility should justify this delay, and we expect to be taking three-wavelength data in the near future.

References

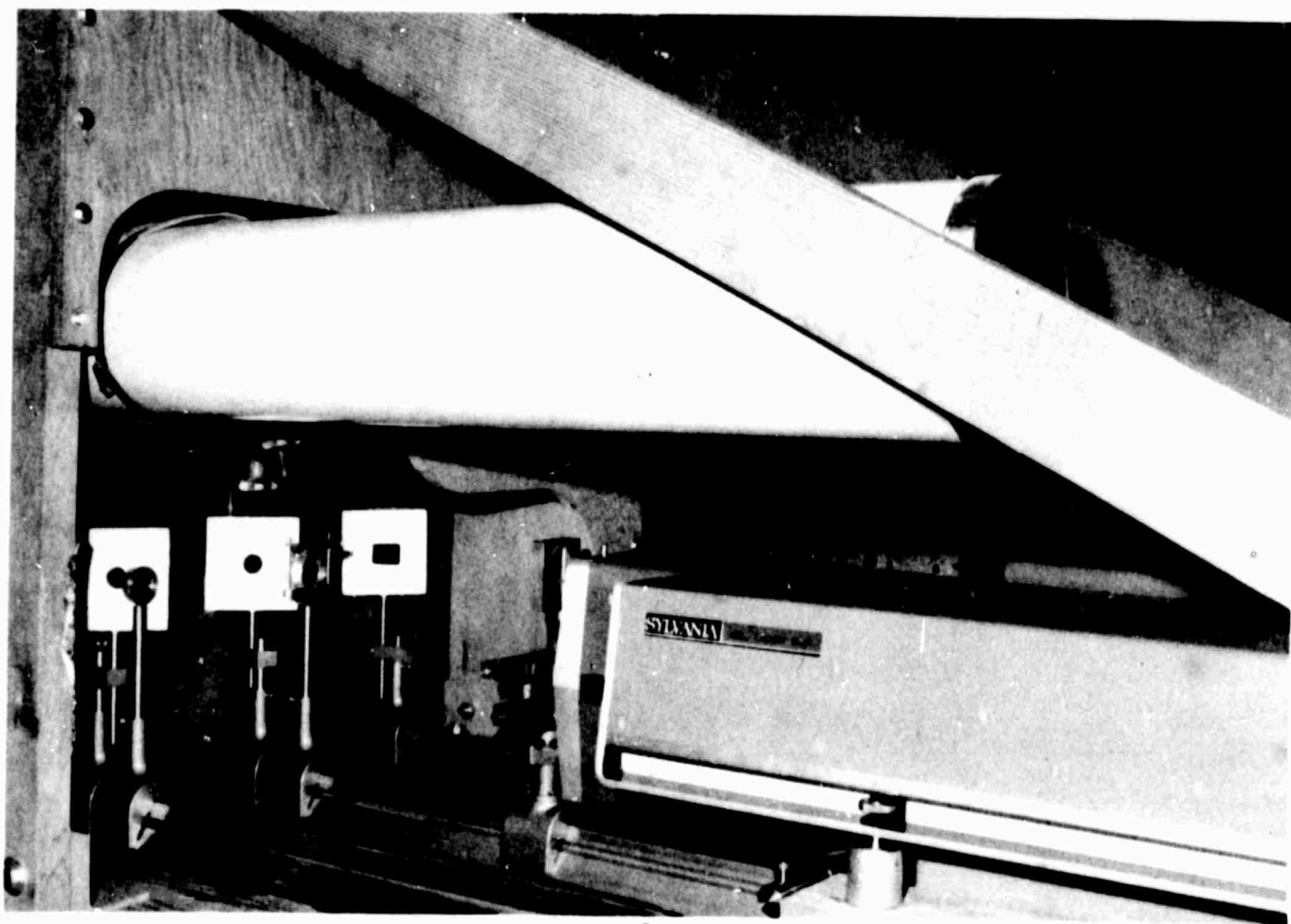
1. Strohbehn, John W., "Line-of-Sight Wave Propagation Through the Turbulent Atmosphere," Proc. IEEE, vol. 56, August 1968, pp. 1301-1318.
2. eWolf, D.A., "Saturation of Irradiance Fluctuations Due to Turbulent Atmosphere," JOSA, vol. 58, April 1968, pp. 461-466.
3. Livingston, P., private communication.
4. Lumley, John L., and Panofsky, Hans A., The Structure of Atmospheric Turbulence, John Wiley and Sons, Inc., New York, 1964.
5. Deitz, Paul H., and Wright, Neal J., "Saturation of Scintillation Magnitude in Near-Earth Optical Propagation," to be published.
6. Hufnagel, Robert E., "An Improved Model Turbulent Atmosphere," Appendix 3, Woods Hole Summer Study, NAS, vol. 2, July 1966.
7. Lawrence, Robert S., private communication.
8. Tatarski, V.I., Wave Propagation in a Turbulent Medium, McGraw-Hill Book Co., Inc., New York, 1961.

CAPTIONS TO FIGURES

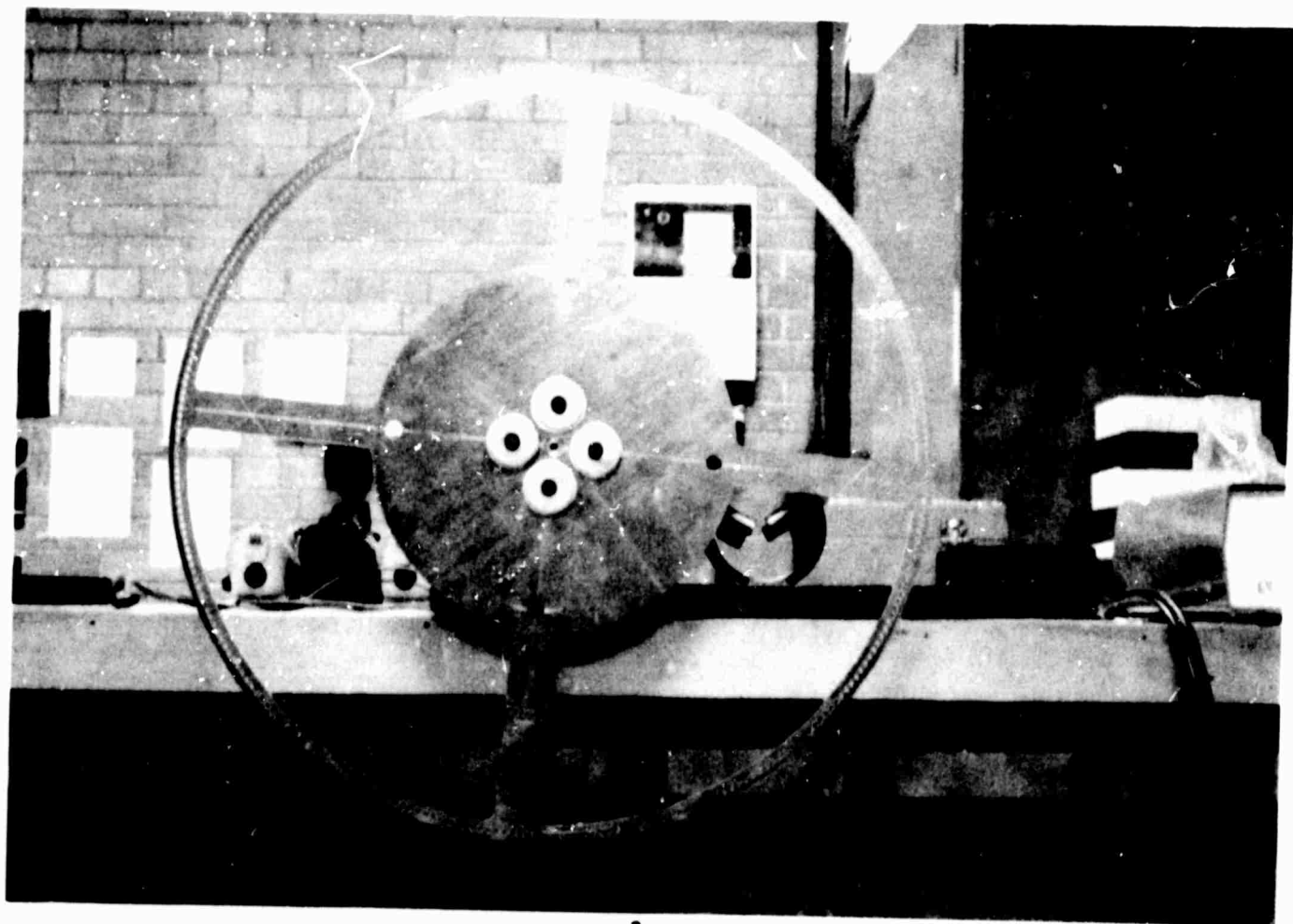
- 1, 2. Three-Wavelength Optical Transmitter
3. 9 kHz Chopping Wheel
4. Spatial-Correlation Receiver Structure
5. Three-Wavelength Detector System
6. Computer Electronics - Typical Modules
7. Transmitter Shack
8. Receiver Shack



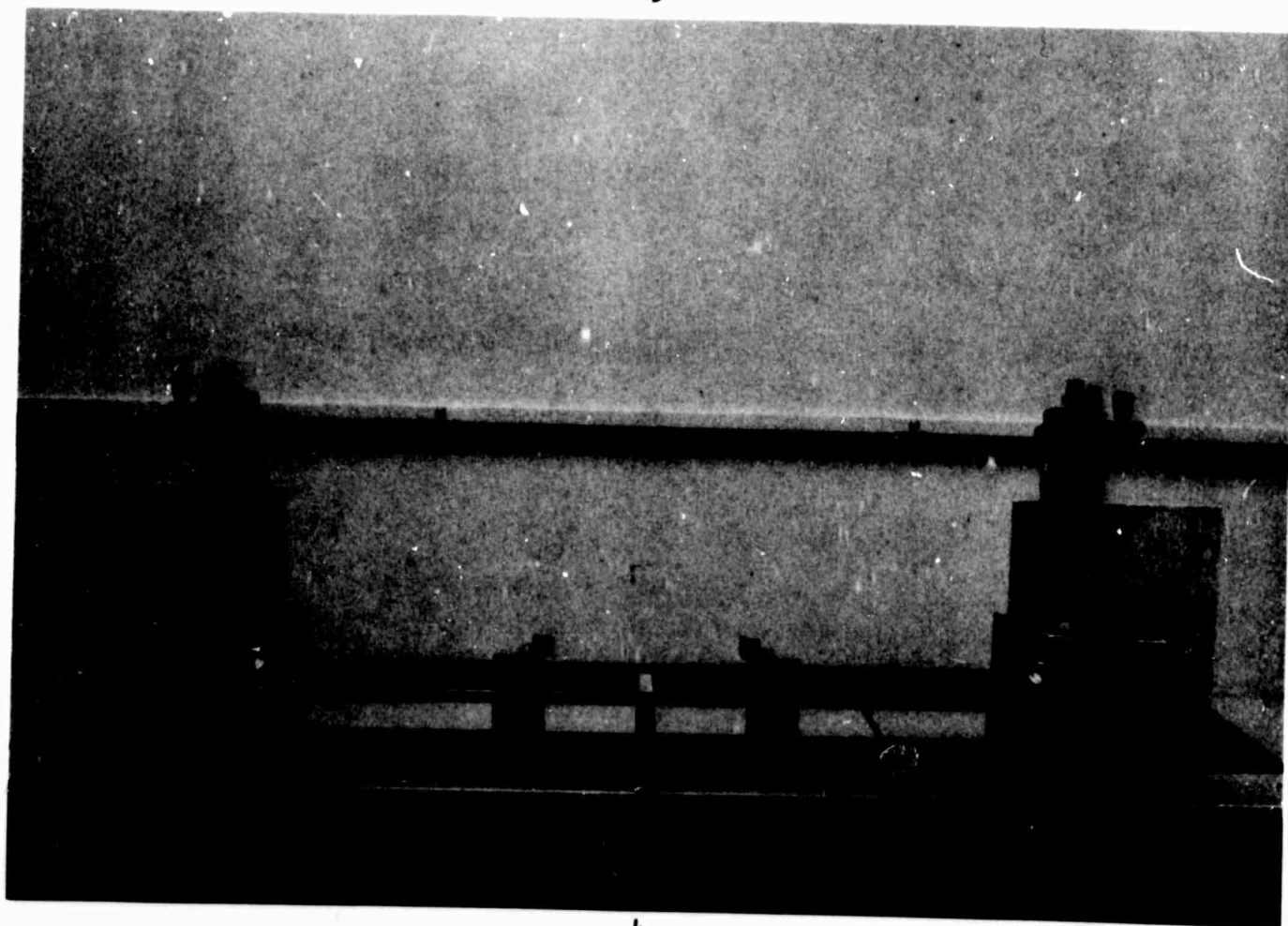
1



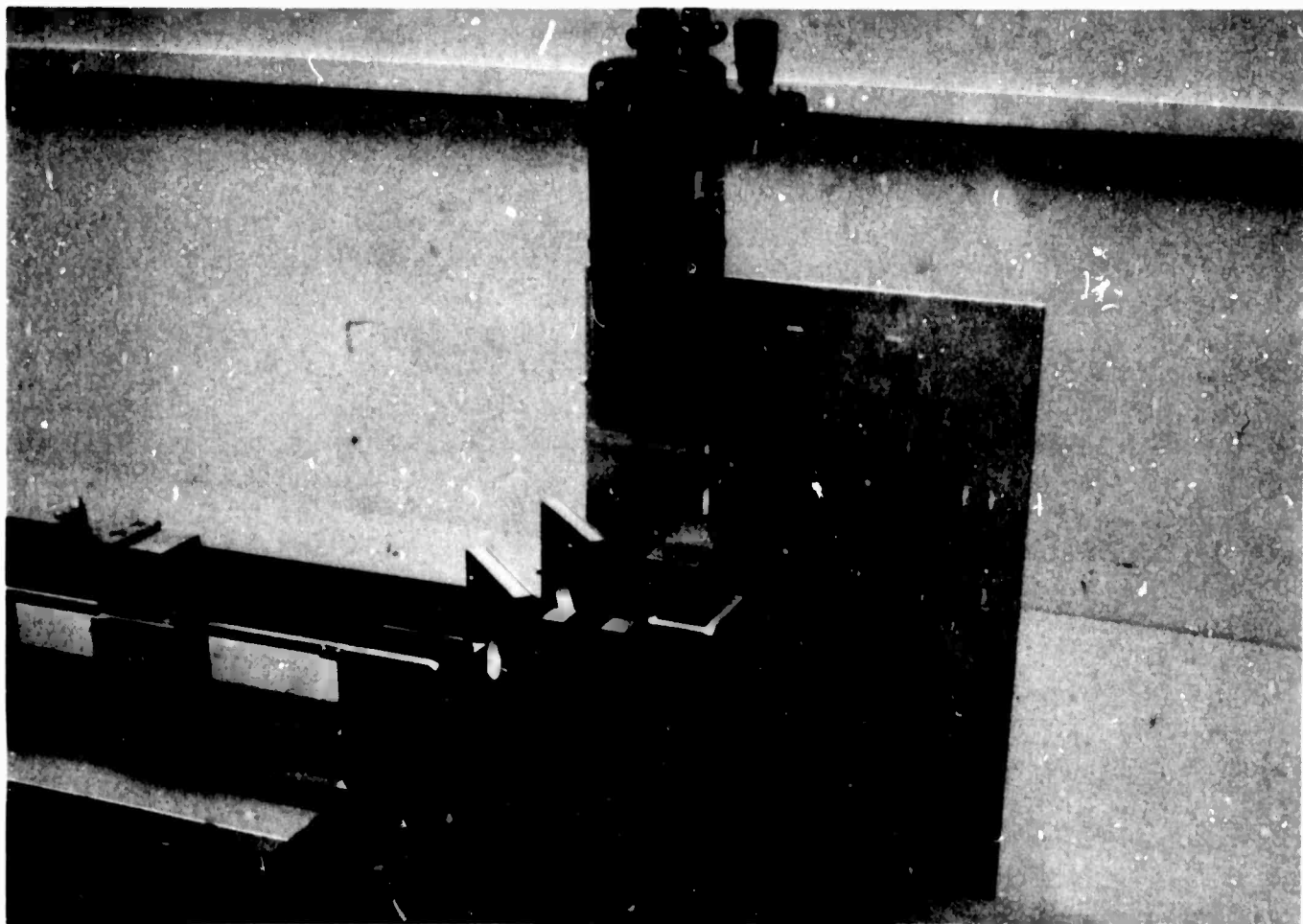
2



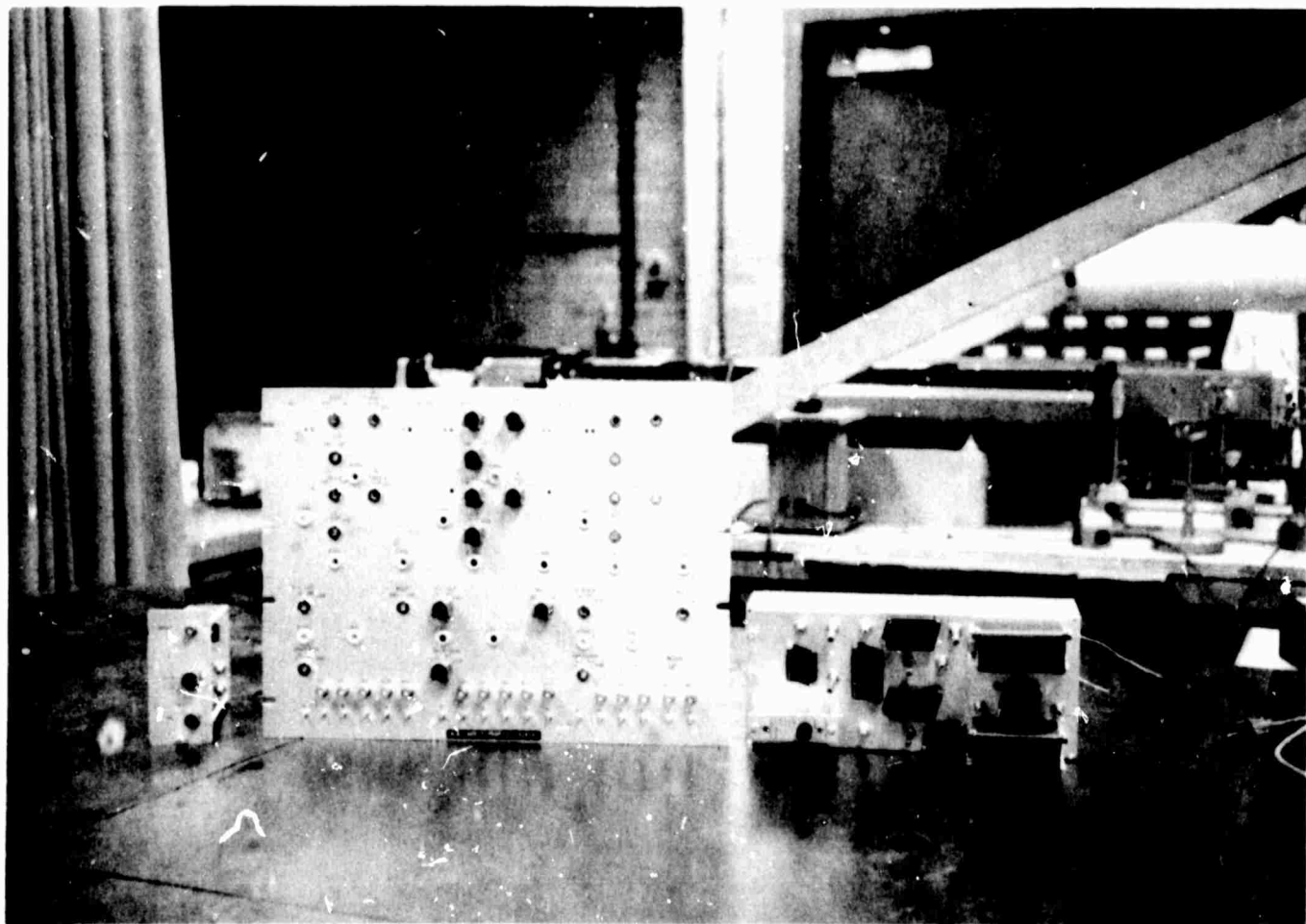
3



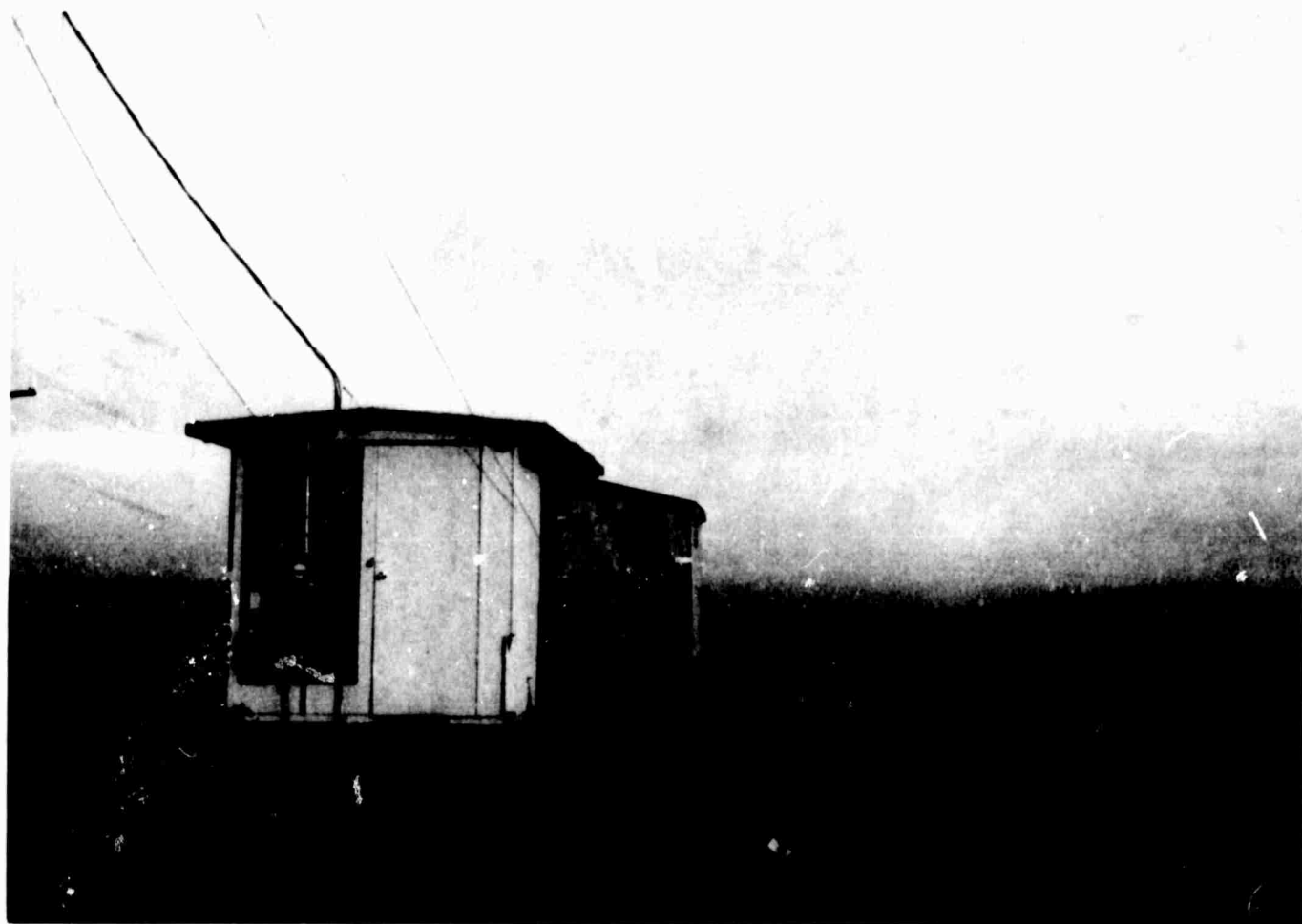
4



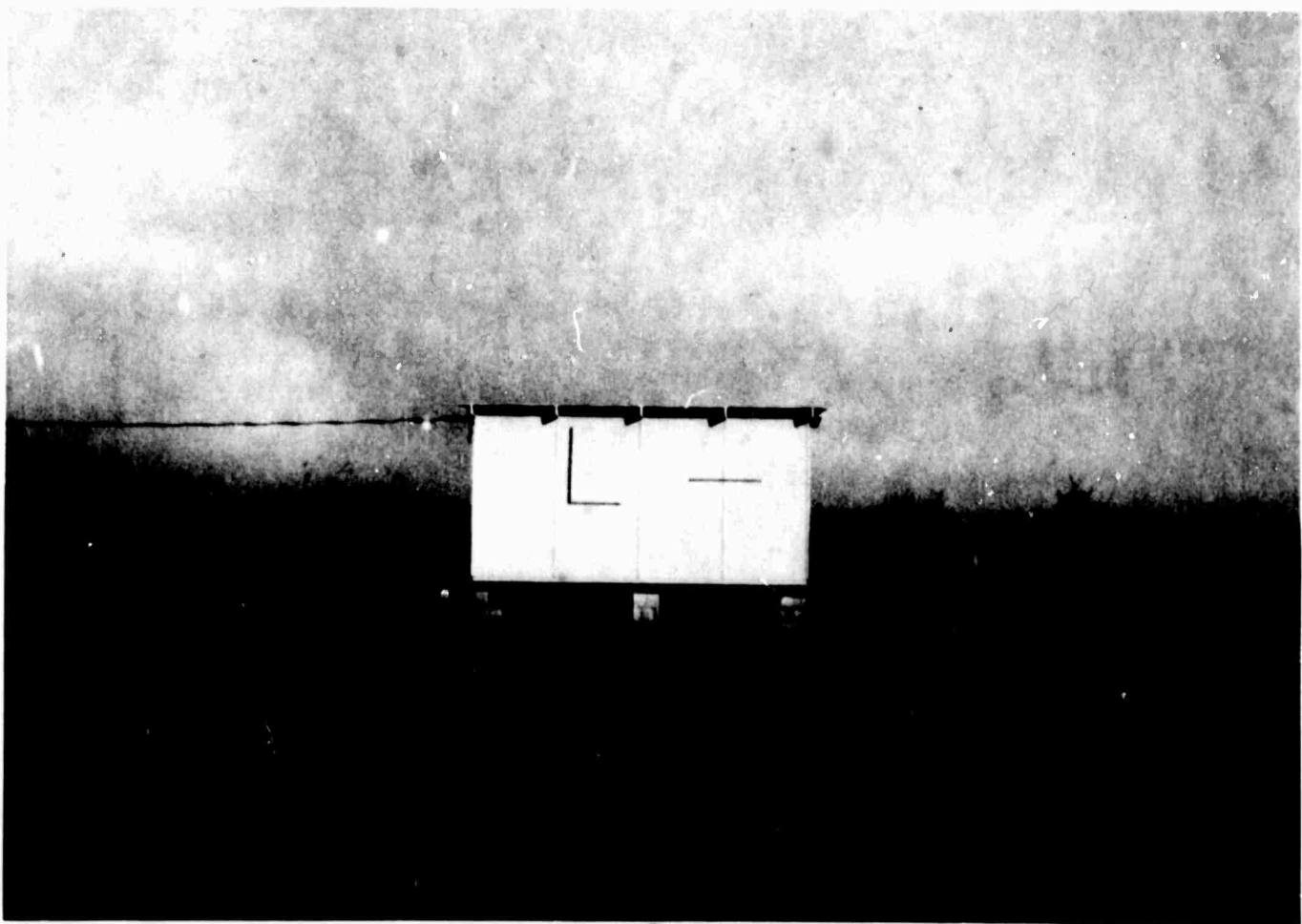
5



6



7



8

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R L D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Oregon Graduate Center 9340 SW Barnes Rd. Portland, Oregon 97225		2a. REPORT SECURITY CLASSIFICATION Unclassified	
3. REPORT TITLE MULTIWAVELENGTH LASER PROPAGATION STUDY		2b. GROUP	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Interim, September 15, 1968-December 15, 1968			
5. AUTHOR(S) (First name, middle initial, last name) J. Richard Kerr			
6. REPORT DATE January 1969		7a. TOTAL NO. OF PAGES 11	7b. NO. OF REFS 8
8a. CONTRACT OR GRANT NO.		9a. ORIGINATOR'S REPORT NUMBER(S) - 1154-2	
b. PROJECT NO.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
c.			
d.			
10. DISTRIBUTION STATEMENT Distribution of this document is unlimited.			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency Department of Defense--Pentagon Washington, D.C. 20301	
13. ABSTRACT The major objective of this program is to experimentally investigate the wavelength-dependence of turbulence effects on optical propagation through the atmosphere, and to relate the results to certain meteorological parameters, theoretical models, and model-independent dimensional analyses. The experiments are conducted with the use of simultaneous, spatially-coincident laser beams at three wavelengths in the visible and infrared spectrum, with real-time processing for the various statistical results. A particular motivation is to establish the validity of wavelength-scaling laws as applied to a growing body of experimental data at visible wavelengths, in order to predict and optimize the performance of systems operating at certain infrared wavelengths. Techniques are emerging which will place great practical value on reliable predictions of turbulence effects for a given site and conditions. During the second period, the low noise, stable lasers were acquired, the three-wavelength transmitter and receiver optical systems were constructed, and the computer electronics were completed. A newly acquired, flat site was established with necessary power, cooling, communications, and protective arrangements. The above systems are currently being installed at the site. The resultant facility will be uniquely suited to atmospheric propagation work, in terms of multiwavelength capability, data processing versatility, meteorological instrumentation, and attention to experimental detail necessary to achieve reliable results in this difficult field of investigation.			

Unclassified

Security Classification

14 KEY WORDS	LINK A		LINK B*		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Visible atmospheric transmission Infrared atmospheric transmission Turbulence scattering Atmospheric propagation						

Unclassified

Security Classification